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International Journal of Obesity (1997) 21, 1143–1151
 0307–0565/97 $12.00

# The effectiveness of long-term supplementation of carbohydrate, chromium, fibre and caffeine on weight maintenance

WJ Pasman[1], MS Westerterp-Plantenga[1,2] and WHM Saris[1]

[1]*Department of Human Biology, Maastricht University, Maastricht and* [2]*Open University, Heerlen, The Netherlands*

**OBJECTIVE: To investigate whether supplementation of carbohydrate, chromium, dietary fibre and caffeine is effective for maintenance of weight-loss in the long-term.**
**DESIGN: A longitudinal, double-blind, randomly assigned intervention study of 16 months with supplementation of either 50g of carbohydrates (CHO), 200 μg chromium-picolinate (Cr-Pic), 20g of soluble fibre plus 100 mg caffeine (CHO+) or 50g of plain CHO, for 16 months besides a very low energy diet (VLED) during the first two months.**
**SUBJECTS: Thirtythree female obese subjects (age, 34.8 ± 7.0 y; body weight (BW): 85.5 ± 10.0 kg; body mass index (BMI) 31.2 ± 3.7 kg.m$^{-2}$) participated, 13 subjects were supplemented with CHO+, 11 subjects were supplemented with CHO and 9 subjects served as a control group.**
**MEASUREMENTS: BW, body composition, energy intake and blood parameters were measured before the VLED (0), after the VLED at 2 months (2), and at 4, 10 and 16 months.**
**RESULTS: The amount and course of relapse of BW was equal for the supplemented and control groups. The average regain at 16 months (the weight gained as a percentage of the total weight loss during the VLED) was 66.1 ± 81.2%, and was not different between the groups. No differences in body composition were found between the groups at 16 months. The CHO supplements resulted in significantly elevated energy percentage (En %) intake of CHO daily, in both supplemented groups, although this did not result in less regain. Pearson correlation analysis for all subjects revealed that the more fat consumed, the more regain was found at 16 months ($r = 0.41$, $P < 0.05$). A high CHO consumption was correlated with less regain ($r = -0.40$, $P = 0.05$). Furthermore, chromium intake did not result in significant changes in blood parameters and body composition.**
**CONCLUSION: Although additional supplementation of CHO, chromium, dietary fibre and caffeine intake did not affect BW, the En % CHO daily was increased significantly. Our results indicate that a high En % intake of CHO and a low En % intake of fat daily is beneficial for prevention of weight regain.**

**Keywords:** long-term weight maintenance; body composition; carbohydrate supplementation; chromium-picolinate

## Introduction

A low-fat diet, exercise and social support are important factors for successful weight maintenance.[1,2] However, results of long-term weight maintenance studies have been disappointing,[3,4] indicating that incorporation of these success factors in normal life is difficult. An increasing number of studies have indicated that obesity could take place as a result of overconsumption of fat, resulting in an overconsumption of energy.[5–8] Besides this, development of obesity could result from insulin resistance and hyperinsulinaemia, without consumption of excess calories.[5] Maintenance of increased levels of adipose tissue lipoprotein lipase (LPL) in the fasted state, and an increased response of adipose tissue LPL to insulin, support the fast uptake and storage of fatty acids, resulting in weight gain.[9] Insulin resistance has therefore been suggested to be an adaptation to prevent ongoing weight gain, when energy intake/fat intake is high and energy expenditure is low.[5,9]

Studies with *ad libitum* intake of energy with a high carbohydrate (CHO) energy percentage (En %), such as that performed by Toubro and Astrup,[10] suggest that a change in macronutrient composition is essential for weight maintenance.[11–13] In addition to better weight maintenance, lowering of insulin resistance has been suggested to take place with lowering of the En % fat on a high-carbohydrate diet, especially with complex carbohydrates.[5,14,15] The high dietary fibre content of the diet would affect the hunger and satiety feelings in such a way that less energy will be consumed.[16,17]

Lowering of insulin resistance has further been suggested by McCarty,[18] with supplementation of chromium, since chromium potentiates the action of insulin. Furthermore, supplementation of chromium has been reported to have positive effects on blood lipid profiles.[19] Patients with insulin resistance syn-

Correspondence: WJ Pasman, Department of Human Biology, Maastricht University, PO Box 616, 6200 MD Maastricht, The Netherlands. E-mail: W.Pasman@HB.Unimaas.N1
Received 8 May 1997; revised 29 July 1997; accepted 12 August 1997

drome, often suffer from dyslipidaemia and chromium supplementation would therefore affect both disorders.[20,21] Besides stimulating glucose-uptake, amino-acid uptake is also stimulated by insulin.[22–24] A lowering of the insulin resistance would result in a higher amino-acid uptake. This anabolic effect of chromium has been reported to result in an increase of lean body mass and a lowering of fat mass.[23,24]

Thus, incorporation of carbohydrate, chromium and dietary fibre as food elements, might be expected to lead to better weight maintenance, because of an increased En% from CHO, improvement in insulin resistance and the reduction of energy intake due to a high-fibre diet. An increase in energy expenditure, as a successful weight maintenance factor, is possible on increasing physical activity, but also by thermogenic agents. Caffeine has been proven to be a potential drug for subjects trying to maintain a stable body weight, or even lose weight, by stimulating energy metabolism and lipolysis.[25]

In the present study, we examined weight maintenance with food supplements rich in CHO, chromium-picolinate (Cr-Pic), caffeine and dietary fibre in weight-reduced subjects. Comparison of this complete supplement with plain carbohydrates will reveal the additional effects of the extra compounds. The main interest in the study is the weight maintenance at 16 months. Changes in body composition, fasting plasma insulin, glucose and serum cholesterol concentrations, and En% of macronutrient intake, were studied.

# Methods

### Subjects

Thirty-three female, obese subjects completed the whole study (age: $34.8 \pm 7.0$ y; body weight (BW): $85.5 \pm 10.0$ kg; body mass index (BMI) $31.2 \pm 3.77$ kg.m$^{-2}$). Written informed consent was obtained from each subject. The study protocol was reviewed and approved by the Medical Ethical Committee of the Maastricht University.

### Drop-out information

At the start of the study, 49 subjects participated. Ten females dropped out of the study during the very low energy diet (VLED) period, because they were not able to follow the strict diet regime. Thirtynine subjects completed the VLED. Three subjects dropped out of the 16 month weight maintenance phase at 5 months, for personal reasons. At 10 months, another 3 subjects dropped out; 2 were unable to complete the tests and 1 complained about the supplement. Comparison of the baseline characteristics of the subjects who dropped out of the study, with those who completed the study, did not reveal any significant differences.

### Study protocol

The subjects took part in a VLED intervention for eight weeks in order to lose weight. The VLED (Modifast®, Novartis Nutrition, Bern, Switzerland) was supplied daily, in three sachets, which were dissolved in water to obtain a milk-shake or dessert. Total energy intake during VLED was 2MJ daily. The maintenance of body weight after VLED was followed for 16 months. The food supplement intervention during this period consisted of either a CHO, Cr-Pic, soluble fibre (Benefiber®, Novartis Nutrition) caffeine supplement (CHO+), or supplementation with plain CHO. The control group did not receive any intervention. Subjects were randomly assigned to a supplement or control group and a double-blind administration of the supplement was carried out. Measurements were carried out before (0 months) and after (2 months) the VLED period. During the weight maintenance phase these measurements were repeated at 4, 10 and 16 months. The study design is presented in Figure 1.

### Food supplements

The two supplements used differed in composition. The CHO+ supplement contained 50 g CHO (42% glucose and 58% maltodextrins), 200 µg Cr-Pic (CHO+), 20 g soluble fibre (Benefiber®) and 100 mg caffeine. The CHO supplement contained 50 g CHO (42% glucose and 58% maltodextrins) (CHO).

The supplement had to be dissolved in 250ml water to obtain a fresh juicy lemonade (flavors: peach, lemon and apple). The food supplements were prepared by Novartis Nutrition. The supplements were consumed once daily. Subjects were instructed to use the CHO+ or CHO supplement in the afternoon to replace the usual in between meals drink, such as a cup of tea or coffee and/or a fat containing snack.

### Measurements

Subjects came to the laboratory at 08.00h after an overnight fast for different measurements at 0, 2, 4, 10 and 16 months.

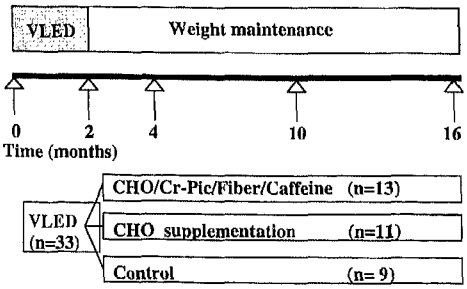


**Figure 1** Study design of the long-term food supplementation study. Already during the 2 months of very low energy diet (VLED), 2 groups were supplemented daily with 2 different kinds of supplements (CHO+ and plain CHO). Measurements were performed before the VLED (0 months), after the VLED (2 months), and at 4, 10 and 16 months.

### Blood analysis

Blood samples (10 ml EDTA and 10 ml serum), were obtained on all test days. Blood for plasma, was mixed with EDTA to prevent clotting and immediately centrifuged. Serum blood was centrifuged after 1h at room temperature. Blood samples were stored at −80°C until further analysis. Plasma glucose was determined by means of a hexokinase method (Cobas Bio, Roche Diagnostics, Hoffman-La Roche, Basle, Switzerland). Plasma insulin was measured using a double antibody radioimmunoassay for human insulin (Kabi Pharmacia Diagnostics AB, Uppsala, Sweden). Total cholesterol (CHOD-PAP method; Monotest cholesterol, Boehringer Mannheim, Mannheim, Germany), HDL cholesterol (precipitation method; Monotest cholesterol, Boehringer Mannheim) and triacylglycerols (GPO-Trinder; Sigma Diagnostics, St Louis, MO, USA) were analyzed enzymatically. LDL cholesterol concentration was calculated by using the Friedewald equation.[26]

### Anthropometry

BW was measured on a digital balance accurate to 0.1 kg (Sauter D-7470, Ebingen, Germany). Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (Seca, model 220, Hamburg, Germany). BMI was calculated from weight and height ($kg.m^{-2}$). The distribution of fat was investigated by measuring waist and hip circumferences, the waist-hip ratio (WHR) and the sagittal diameter. The waist circumference was measured at the smallest circumference between the rib cage and the ileac crest, with the subject standing. The hip circumference was measured at the level of the widest circumference between the waist and thighs. The WHR was calculated by dividing the waist circumference by the hip circumference. For determination of the sagittal diameter, the distance between the abdomen and the back, a stadiometer was used with the subject supine.

### Bio-impedance spectrometry

Multiple frequency bio-electrical impedance analyses were measured with a Xitron 4000 Multi-Frequency Bio-Impedance Analyzer (Xitron Technologies, San Diego, CA, USA). This device uses a four-electrode arrangement and measures reactance and phase angle of a conductor on application of an alternating electric current. Tracets MP3000 (LecTec Corporation, Minnetonka, MN, USA) electrodes were used. The applied frequency ranged from 1 kHz to 1.35 MHz. Measurements were made while the subjects were lying comfortably on a polysterene mattress, their legs slightly apart to ensure no contact between the thighs and the arms relaxed at the side to prevent contact with the trunk. The electrodes were positioned at conventional locations on the hand and foot. Measurements were made one-sited at the right site of the body. The calculations of Fat Free Mass (FFM) and Fat Mass (FM) were performed with Triton 4000B. Extracellular water (ECW) and intracellular water (ICW) were predicted using the general mixture theory. This implies that we used a formula to directly calculate the water compartments from resistance values, assuming specific resistance of ECW and ICW. The specific resistances used for women was extracellularly = 146.4 and intracellularly = 947; these values were obtained from an independent dataset of our laboratory.[27,28]

### Energy intake

The amount of food consumed during the 16 month study period, was calculated with analysis of the completed food-intake diary. Subjects were asked to write down everything consumed (meals, drinks and snacks) on two normal week days and one weekend day at every time point of the study. After returning the diaries, the portion size and household attributes were examined to give a good indication of the amount of food consumed. The diaries were analysed with the Dutch food table[29] and the accessory computer program.

### Compliance to supplement intake during the weight maintenance phase

The supplemented subjects were asked to consume 1 sachet daily. Actual intake was checked by lists of supplement intake and counting of the returned sachets. The 24 supplemented subjects liked the supplement and hardly forgot consumption. Compliance was 86 ± 15% on average for the CHO + group and 84 ± 18% for the CHO group.

### Statistics

Data are presented as mean and standard deviation (± s.d.). A two-way ANOVA with repeated measurements was used to compare differences in parameters across the groups over time. Changes in parameters measured with respect to the initial value were calculated as a percentage of the initial value. Statistical significance was set at $P < 0.05$. Power analysis (power 0.80) was performed *a priori*, based upon data of a previous supplementation study.[30] A difference in regain between groups of 60% and a standard deviation of 60%, revealed that we needed 3 groups of 12 subjects for our study. Based upon a drop-out estimation of 10 subjects, we started with 49 subjects.

## Results

The physical characteristics of the subjects before the intervention are presented in Table 1. For the anthropometric parameters measured (BW, WHR, sagittal diameter, body fat percentage, FFM and FM) two-way ANOVA analysis revealed significant differences over

**Table 1** Baseline characteristics. The data of all 33 subjects before the study are presented and compared for the three groups

| | *CHO +* *(n = 13)* | *CHO* *(n = 11)* | *Control* *(n = 9)* |
|---|---|---|---|
| Age (y) | 36.2 (7.0) | 32.6 (7.4) | 35.6 (6.5) |
| Height (m) | 1.69 (0.02) | 1.63 (0.07) | 1.65 (0.03) |
| Weight (kg) | 86.3 (8.5) | 85.5 (13.5) | 84.2 (7.7) |
| BMI ($kg.m^{-2}$) | 30.4 (0.89) | 32.1 (4.6) | 31.2 (3.5) |
| WHR | 0.81 (0.04) | 0.81 (0.05) | 0.82 (0.06) |
| Sag.$\phi$ (cm) | 20.3 (1.7) | 21.2 (2.6) | 20.7 (1.6) |
| BPsys (mm Hg) | 125.1 (12.3) | 125.1 (14.9) | 134.4 (16.5) |
| BPdia (mm Hg) | 83.0 (9.7) | 85.1 (13.6) | 86.9 (11.3) |
| Glucose ($mmol.L^{-1}$) | 5.10 (0.46) | 5.29 (0.15) | 5.31 (0.53) |
| Insulin ($\mu U.ml^{-1}$) | 10.3 (3.6) | 13.4 (5.2) | 13.9 (4.6) |

No significant differences were found in physical characteristics. Mean and standard deviations (in parentheses) are presented.
BMI = body mass index; WHR = waist–hip ratio; Sag. $\phi$ = BDsys = systolic blood pressure; BDdia: diastolic blood pressure.

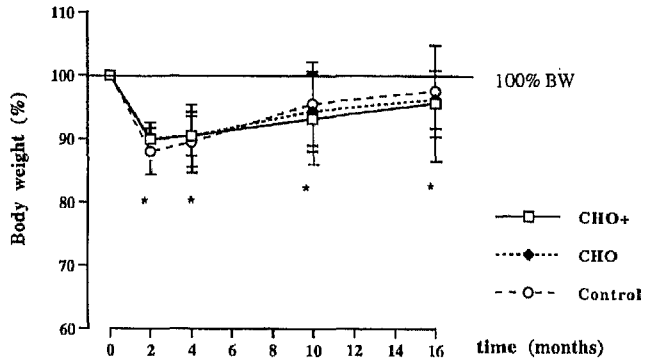


**Figure 2** The changes in body weight are expressed as a percentage of the initial value. The mean and s.d. are presented at different time points measured, for the CHO+ group (open squares), CHO group (filled diamonds) and control-group (open circles).

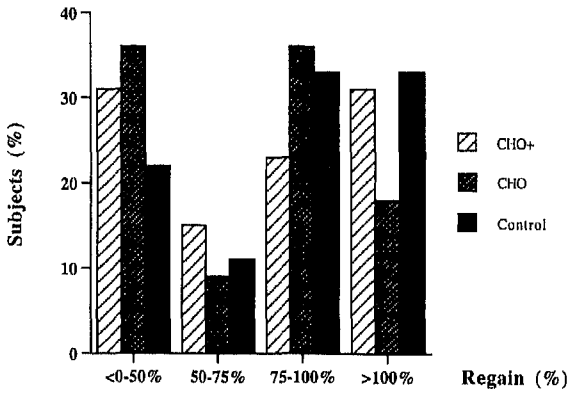


**Figure 3** Weight regain at 16 months. Weight regain is presented as a percentage of the amount of weight lost during the very low energy diet (VLED). The VLED intervention resulted in a significant weight loss for all three groups. The amount of weight lost during the VLED was set at 100%. The percentage of subjects in the three groups that gained different amounts of body weight (BW) are presented for the CHO+ group (light hatched bars), CHO group (dark hatched bars) and control group (filled bars).

time for all parameters, but no differences among the three groups. Subjects lost on average $9.0 \pm 2.4$ kg during the VLED (no differences between groups). Body weight decreased on average to $89.5 \pm 2.7\%$ of the initial BW. The changes in BW are presented in Figure 2, which illustrates weight fluctuation in the different groups during the study. The amount and course of changes in BW was equal for the supplemented and control groups. At 16 months of the study, all three groups still had significantly lower BW than at month 0. The classification of subjects according to the amount of weight regained at 16 months (as a percentage of the weight lost during the VLED) is shown in Figure 3. The average regain at 16 months was $66.1 \pm 81.2\%$, and was similar for all the groups ($51.1 \pm 109.0\%$ for CHO+, $68.1 \pm 55.2\%$ for CHO and $85.5 \pm 55.8\%$ for the control group). Leaving one subject of the CHO+ group out of the analysis because of ongoing weight loss during the weight maintenance phase, resulted in a percentage of $76.6 \pm 62.7$ at 16 months for the CHO+ group. In Figure 3 it is shown that 31% of the CHO+ group, 36% of the CHO group and 21% of the control group regained less than 50% of the weight lost.

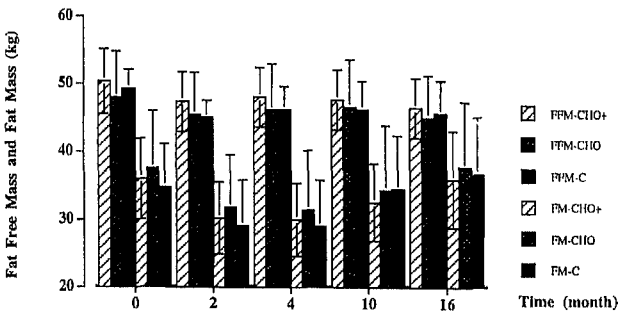


**Figure 4** The absolute amount of fat free mass (FFM) and fat mass (FM) are shown for the CHO+ group (light hatched bars), CHO group (dark hatched bars) and control group (filled bars) at different time points of the study.

FFM and FM, as measured with bio-impedance, are presented in Figure 4. No differences in body composition were found between the groups, although clear differences were found over time. FFM was, at 16 months, still significantly lower compared to baseline values. For FM this was not found; although BW was still lower at 16 months, FM was already completely

**Table 2** Blood parameters. Serum cholesterol levels are shown for the three groups. Total cholesterol, HDL and LDL data are presented for the three groups in mmol.L$^{-1}$. Glucose and insulin data are also presented in mmol.L$^{-1}$

| | *Month* | | | | |
|---|---|---|---|---|---|
| | *0* | *2* | *4* | *10* | *16* |
| Total cholesterol (mmol.L$^{-1}$)* | | | | | |
| CHO+ | 5.1±1.1 | 4.5±0.8 | 5.1±0.9 | 5.3±1.2 | 5.3±0.9 |
| CHO | 4.9±0.9 | 4.3±1.0 | 4.8±1.0 | 4.9±1.0 | 5.0±1.0 |
| control | 5.9±0.5 | 4.9±0.5 | 5.3±0.5 | 5.9±1.0 | 6.0±0.8 |
| HDL (mmol.L$^{-1}$)* | | | | | |
| CHO+ | 1.3±0.5 | 1.3±0.2 | 1.5±0.2 | 1.7±0.3 | 1.6±0.3 |
| CHO | 1.3±0.3 | 1.1±0.3 | 1.4±0.2 | 1.6±0.4 | 1.4±0.2 |
| control | 1.5±0.3 | 1.4±0.3 | 1.4±0.3 | 1.6±0.3 | 1.6±0.4 |
| LDL (mmol.L$^{-1}$)* | | | | | |
| CHO+ | 3.3±1.1 | 2.9±0.8 | 3.4±1.0 | 3.3±1.0 | 3.3±0.9 |
| CHO | 3.2±0.7 | 2.8±0.8 | 3.1±0.9 | 3.1±0.9 | 3.3±1.0 |
| control | 3.9±0.4 | 3.1±0.4 | 3.5±0.6 | 3.9±0.8 | 3.8±0.6 |
| Glucose (mmol.L$^{-1}$)* | | | | | |
| CHO+ | 5.1±0.5 | 4.7±0.4 | 4.9±0.4 | 4.9±0.4 | 4.7±0.4 |
| CHO | 5.3±0.5 | 4.8±0.4 | 5.0±0.4 | 4.9±0.3 | 4.7±0.3 |
| control | 5.3±0.5 | 4.8±0.4 | 4.9±0.5 | 4.9±0.3 | 4.7±0.5 |
| Insulin (mmol.L$^{-1}$)* | | | | | |
| CHO+ | 10.3±3.6 | 9.0±2.8 | 10.0±3.1 | 11.1±3.1 | 9.4±1.9 |
| CHO | 13.5±5.2 | 10.1±3.9 | 11.8±5.1 | 11.9±4.8 | 10.1±3.0 |
| control | 13.9±4.6 | 8.8±2.7 | 9.3±2.0 | 12.6±3.5 | 10.5±4.1 |

Mean and standard deviations are presented. *significant difference over time ($P < 0.05$).

the same as at the beginning of the study (see Figure 4).

Serum cholesterol data and fasted plasma glucose and insulin values are presented in Table 2. No influence of CHO supplementation or the additional compounds was found, meaning that there were no differences among the 3 groups in this study. Comparable changes over time were found for the three groups caused by the VLED intervention.

Because an extra intake of 50 g of CHO daily would affect macronutrient composition of the diet, the energy intake and composition are shown (Table 3). The EI differed significantly over time, but was similar in the three groups. Significant differences in CHO En% intake, were found between the two supplemented groups and the control group; En% CHO intake was significantly higher during the supplemented phase in the CHO+ (52.0 En% CHO) and CHO group (50.3 En% CHO) compared with the control group (42.9 En% CHO) (two-way ANOVA; $P < 0.01$ among groups). Pearson-correlation analysis revealed that for the whole group, the more En% CHO ingested daily (average intake at 10 months and 16 months) the less regain took place ($r = -0.40$, $P = 0.05$) (Figure 5). When corrected for energy-intake, a partial correlation coefficient for CHO intake and body weight regain of $-0.40$ was found ($P < 0.05$). For the average fat intake at 10 months and 16 months, a positive relation with regain of BW was found as shown in Figure 6; $r = 0.41$ ($P < 0.05$). Correction for energy-intake revealed a partial correlation coefficient of 0.40 between fat intake and BW ($P < 0.05$). Relative changes in BW were also significantly correlated with En% CHO and fat intake at 0 months and 16 months. En% CHO intake and relative changes in BW at 10 months and 16 months were $r = -0.54$ ($P < 0.01$) and $r = -0.42$ ($P < 0.05$), respectively, indicating that a higher En% CHO-intake is correlated with less changes in BW. For En% fat intake, positive relations were found; at 10 months $r = 0.45$ ($P < 0.05$) and at 16 months $r = 0.49$ ($P < 0.05$).

## Discussion

In this study an attempt was made to improve weight maintenance success over a 14 month period by means of a food supplement in order to increase the CHO, fibre, caffeine and chromium content of the diet. All components have a potential capacity to facilitate weight maintenance. The results did not show a beneficial effect on weight maintenance, although the increased En% of CHO intake for the whole day was related to lowered weight regain. It can not however be ruled out that the number of subjects participating in our study was too small. Based upon results of weight maintenance with fibre supplementation,[30] we calculated that with a power of 0.80, a difference in regain of 60% could be detected with this number of subjects. The results of the study indicate that the supplement effectiveness was far below the calculated power.

### Weight maintenance and macronutrient intake

The CHO-containing supplements, used in the present study, did not result in weight maintenance. Studies where fat is replaced with CHO, have been carried out to manipulate fat balance. *Ad libitum* food intake studies, in which CHO has provided an energy percentage of 55%,[10,31,32] have shown positive outcomes for weight maintenance and weight loss. The theory of

**Table 3** Energy intake and macronutrient composition. Mean energy intake (MJ.day$^{-1}$) of 24 completed food intake diaries are presented at different time points of the study for the three groups

| | Month | | | | |
|---|---|---|---|---|---|
| | *0* | *2* | *4* | *10* | *16* |
| EI (MJ.day$^{-1}$)* | | | | | |
| CHO+ | 8.6±2.9 | 6.6±1.7 | 6.8±1.3 | 7.4±2.1 | 8.0±1.8 |
| CHO | 8.9±2.1 | 7.7±2.1 | 8.3±1.2 | 9.0±2.1 | 8.1±1.5 |
| Control | 9.1±3.2 | 5.6±1.9 | 6.6±2.5 | 6.6±1.7 | 7.6±1.9 |
| Protein (En%)*, ** | | | | | |
| CHO+ | 15.3±3.1 | 17.0±2.4 | 15.7±2.3 | 14.4±2.1 | 14.9±2.0 |
| CHO | 13.8±1.3 | 13.8±2.5 | 13.4±2.7 | 11.8±1.7 | 13.1±1.8 |
| Control | 14.9±3.9 | 21.3±5.3 | 17.3±3.3 | 15.5±2.0 | 14.8±3.4 |
| CHO (En%)*, ** | | | | | |
| CHO+ | 41.1±4.3 | 53.6±5.8 | 52.9±5.4 | 52.7±4.6 | 48.8±4.4 |
| CHO | 45.8±6.9 | 52.1±4.3 | 49.6±3.6 | 49.4±4.2 | 50.3±5.0 |
| Control | 39.1±7.1 | 41.8±7.4 | 43.6±8.2 | 44.1±8.8 | 42.0±8.1 |
| Fat (En%) | | | | | |
| CHO+ | 40.9±6.2 | 28.4±6.8 | 29.0±5.7 | 31.3±4.3 | 34.7±4.2 |
| CHO | 37.9±5.3 | 32.2±3.5 | 35.3±3.6 | 38.4±3.7 | 36.0±5.6 |
| Control | 39.4±5.6 | 30.5±8.3 | 32.4±9.2 | 35.3±9.0 | 37.1±7.1 |
| Alcohol (En%)** | | | | | |
| CHO+ | 2.7±3.6 | 1.0±1.3 | 2.4±2.7 | 1.7±2.0 | 1.6±2.6 |
| CHO | 2.5±3.8 | 1.9±2.8 | 1.6±2.0 | 0.3±0.7 | 0.6±1.1 |
| Control | 6.6±7.1 | 6.4±8.3 | 6.7±7.1 | 5.2±5.0 | 6.1±6.3 |
| Fibre (g.day$^{-1}$)*, ** | | | | | |
| CHO+ | 14.8±3.7 | 32.4±1.6 | 33.8±3.5 | 33.1±4.0 | 35.3±4.4 |
| CHO | 12.7±4.1 | 12.4±4.5 | 12.4±3.9 | 14.2±4.8 | 12.2±4.0 |
| Control | 14.5±5.5 | 12.2±4.0 | 12.8±3.3 | 14.0±4.5 | 14.5±3.9 |

*significant difference over time ($P < 0.05$).
**significant difference between groups ($P < 0.05$).
EI = Energy intake. En% = energy percentage.

Flatt[11,33] that fat storage will not take place when FQ > RQ, illustrates that a high CHO diet will improve weight maintenance. This theory is supported by our findings that, when all subjects were studied as one group because no differences in regain of BW were found between the groups, the En% of CHO intake was negatively related with BW-regain. The more CHO consumed, the less regain took place. Calculated from the regression line, no regain took place when 57 En% of CHO were consumed. Fat-intake was positively correlated with BW-regain; more En% of fat intake showed more regain of BW (28 En% intake of fat, revealed no regain). No relation was found between total energy intake and regain of BW at 16 months. Partial regression analysis revealed still significant correlation coefficients between the macronutrient intake and BW regain. These results support the theory that macronutrient composition is of importance in addition to total energy intake consumed daily.[10,13,31,34] This result agrees with the general finding that high-fat diets result in obesity.[6,35] The fact that supplementation of CHO, as performed in this study, is not effective for weight maintenance, but overall increased CHO-intake and lowered fat-intake is related to less BW-regain, seems to suggest that supplementation of one food element is not the solution for maintenance of a stable BW. The total food consumed during the day,

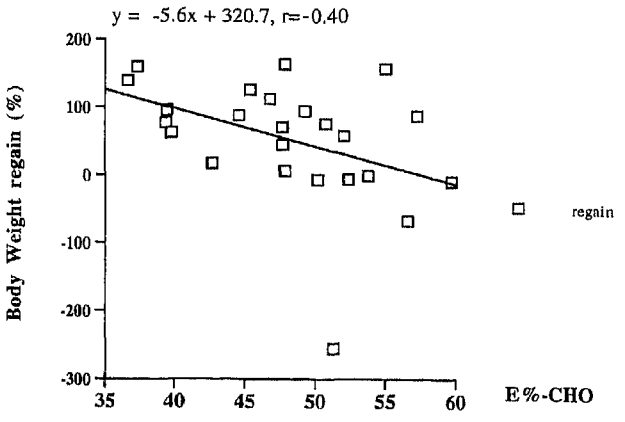


**Figure 5** The relation between the daily total energy percentage (En%) carbohydrate (CHO) intake and regain of body weight at 16 months is shown for the whole group. The positive relation found indicates that the more CHO were consumed, the less regain was found.

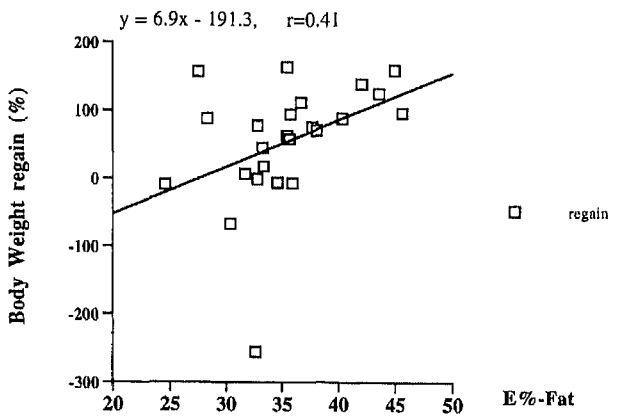


**Figure 6** The relation between the daily total energy percentage (En%) fat intake and regain of body weight at 16 months is shown for the whole group. Regain was higher when more fat was consumed.

especially under free living conditions, is of more importance. It should therefore be emphasized that normal food consumption during the day should contain low-fat and CHO-rich food products for beneficial effects at weight maintenance.

**Body composition**

In the studies described by Evans,[23,24] showing an effect of Cr-Pic supplementation on body composition, the body fat percentages were determined with skin folds measurements. Knowing the inaccuracy of this method in obese subjects,[36,37] we studied body composition by bio-impedance. No differences in body fat percentage was found between the three groups as a consequence of Cr-Pic supplementation. Our results are in agreement with Trent and Thieding-Cancel,[38] who studied the effect of 400 μg Cr-Pic on body composition. Although they used a higher dosage of Cr-Pic, that is suggested to be more effective particularly in men, no effect on body fat percentage was found. Other studies used hydrodensitometry, known as a good qualitative method for body composition determination.[39] Densitometry was used by Clancy *et al*[40] and Hallmark *et al*,[41] who also found no effect of 200 μg Cr-Pic supplementation combined with fitness training for 9–12 weeks, respectively, on body composition.

Calculation of the Body Composition Improvement-score (BCI-score) as performed by Kaats *et al*[42] to study the effect of Cr-Pic supplementation, did not result in differences between the groups in this study. Our results are in contrast to the results of Kaats *et al*[42] who found positive changes in body composition after 72 days of supplementation with 200 and 400 μg Cr-Pic. The addition of FM losses and increases in FFM in the BCI-scores was negative for all groups in the present study (CHO+: $-3.9 \pm 4.3$; CHO: $-3.2 \pm 4.2$; Control: $-5.6 \pm 3.5$), indicating that the intervention in the long-term, resulted in an impaired body composition. Therefore the anabolic effect of chromium remains under debate.

**Effectiveness of Cr-Pic on blood parameters**

Although positive effects of chromium supplementation have been found with respect to glucose tolerance,[19] the results of our study indicate that supplementation with Cr-Pic was not effective on fasted glucose and insulin concentrations. A possible explanation would be that the subjects participating in this study were not Cr-deficient (as discussed below). With respect to lipid metabolism, Mertz[19] reported that 4 out of 8 studies found no, and 4 studies found positive, effects of chromium supplementation on cholesterol. Although the effect of supplementation is under debate, Newman et al[43] reported in 1978 that serum chromium was significantly lower in patients with coronary artery disease (CAD). Serum chromium was even suggested to be a clinical parameter for prediction of future CAD.

Several explanations for the lack of effect of Cr-Pic supplementation, are possible. The first and most important possible explanation could be that the participating subjects had no insulin resistance and were not Cr-deficient. The fasted plasma glucose and insulin concentrations of our subjects were not pathological (plasma glucose $< 8 \text{mmol.L}^{-1}$ and plasma insulin $< 20 \text{mU.L}^{-1}$) This was further supported by the finding that the area under the curves (AUC) of the oral glucose tolerance tests (OGTT) performed in the two supplemented groups (data not shown), did not change at all with supplementation of CHO+ or CHO. In the United States, based upon results with self-selected diets, it is assumed that 90% of the population have deficient Cr-intake ($< 50$ μg daily).[44] This will, however, not necessarily mean that the risk factor for impaired glucose tolerance is increased. Uusitupa *et al*[45] found that although elderly subjects in Finland consumed on average $< 30 \text{ μg.day}^{-1}$ of Cr, this was not found to be an important risk factor for impaired glucose tolerance. Long-term supplementation of 160 μg Cr per day was not effective in normalizing glucose and insulin metabolism.

Compliance of the supplement intake was thoroughly checked and appeared to be high (85%), and low compliance is therefore ruled out as a possible explanation for finding no effects of supplementation. The chelating agent for Cr, picolinic acid, has been studied by Evans[23,24] and was suggested to be the best chelating agent for Cr. The dosage of Cr-Pic, supplemented in this study (200 μg daily approx. 4 μmol Cr daily) was in the same range used in other studies, that proved, for example, to be effective in: lowering cholesterol[19] and triglyceride concentrations;[21] improving insulin sensitivity[19] and having beneficial effects on body composition (lowering FM and increasing FFM).[23,24,42] Therefore the dosage of Cr supplemented was not the limitation in this study, however the combination of Cr-Pic with other nutrients (like CHO and dietary fibre) could be, resulting in a lowered uptake of Cr-Pic.

Of the other ingredients, conflicting results have been found before. Although caffeine is known for its thermogenic effect and stimulation of thermogenesis,[46] this was not always found.[25] The same is true for dietary fibre, which was found to be effective as a supplement in short-term studies,[47] however, in our previous long-term fibre supplementation study, no beneficial effects were found with respect to weight maintenance.[30]

**Conclusion**

Supplementation of either CHO in combination with Cr-Pic, dietary fibre and caffeine or CHO alone, has no beneficial effect on weight maintenance in the long-term. No changes in body composition, glucose, insulin and cholesterol were found, suggesting that supplementation was not effective under free living

conditions. However, overall En% from CHO-intake and fat-intake were significantly correlated with BW-regain, indicating that macronutrient composition of the diet, influences regain of BW. Attention should be given to the macronutrient composition of the total food consumed during the day, to stimulate CHO-rich and low-fat food consumption in normal daily life.

**Acknowledgement**
This study was financially supported by Novartis Nutrition Ltd, Bern, Switzerland.

**References**

1 DuPue JD, Clark MM, Ruggiero L, Medeiros ML, Pera V. Maintenance of weight loss: a needs assessment. *Obes Res* 1995; **3**: 241–248.
2 Kayman S, Bruvold W, Stern J. Maintenance and relapse after weight loss in women: behavioral aspects. *Am J Clin Nutr* 1990; **52**: 800–807.
3 Garner DM, Wooley SC. Confronting the failure of behavioral and dietary treatments for obesity. *Clin Psych Rev* 1991; **11**: 729–780.
4 Rössner S. Factors determining the long-term outcome of obesity treatment. In: Björntorp P and Brodoff BN (eds). *Obesity*, JB Lippincott Company: Philadelphia, 1992, pp 712–719.
5 Barnard RJ, Wen SJ. Exercise and diet in the prevention and control of the metabolic syndrome. *Sports Med* 1994; **18**: 218–228.
6 Lissner L, Levitsky DA, Strupp BJ, Kalkwarf HJ, Ro DA. Dietary fat and the regulation of energy intake in human subjects. *Am J Clin Nutr* 1987; **46**: 886–892.
7 Dreon DM, Frey-Hewitt B, Ellsworth N, Williams PT, Terry RB, Wood PD. Dietary fat:carbohydrate ratio and obesity in middle-aged men. *Am J Clin Nutr* 1988; **47**: 995–1000.
8 Romieu I, Willett WC, Stampfer MJ, Colditz GA, Sampson L, Rosner B, Hennekens CH, Speizer FE. Energy intake and other determinants of relative weight. *Am J Clin Nutr* 1988; **47**: 406–412.
9 Eckel RH. Insulin resistance: an adaptation for weight maintenance. *Lancet* 1992; **340**: 1452–1453.
10 Toubro S, Astrup A. Randomised comparison of diets for maintaining obese subjects' weight after major weight loss: ad lib, low fat, high carbohydrate diet *v* fixed energy intake. *BMJ* 1997; **314**: 29–34.
11 Flatt JP. Dietary fat, carbohydrate balance, and weight maintenance: effects of exercise. *Am J Clin Nutr* 1987; **45**: 296–306.
12 Blaak EE, Saris WHM. Health aspects of various digestible carbohydrates. *Nutrition Research* 1995; **15**: 1547–1573.
13 Astrup A, Raben A. Carbohydrate and obesity. *Int J Obes* 1995; **19 (Suppl. 5)**: S27–S37.
14 McCarty MF. Reduction of free fatty acids may ameliorate risk factors associated with abdominal obesity. *Med Hypotheses* 1995; **44**: 278–286.
15 Fukagawa NK, Anderson JW, Hageman G, Young VR, Minaker KL. High-carbohydrate, high-fiber diets increase peripheral insulin sensitivity in healthy young and old adults. *Am J Clin Nutr* 1990; **52**: 524–528.
16 Evans E, Miller DS. Bulking agents in the treatment of obesity. *Nutr Metab* 1975; **18**: 199–203.
17 Spiller GA. *Handbook of dietary fiber in human nutrition*, 2nd edn. CRC Press: Boca Raton, 1993.
18 McCarty MF. Insulin resistance in mexican Americans–a precursor to obesity and diabetes? *Med Hypotheses* 1993; **41**: 308–315.
19 Mertz W. Chromium in human nutrition: a review. *J Nutr* 1993; **123**: 626–633.
20 Godsland IF and Stevenson JC. Insulin resistance: syndrome or tendency? *Lancet* 1995; **346**: 100–103.
21 Lee NA and Reasner CA. Beneficial effect of chromium supplementation on serum triglyceride levels in NIDDM. *Diabetes Care* 1994; **17**: 1449–1452.
22 Felig P. Insulin is the mediator of feeding-related thermogenesis: insulin resistance and/or deficiency results in a thermogenic defect which contributes to the pathogenesis of obesity. *Clin Phys* 1984; **4**: 267–273.
23 Evans GW. The effect of chromium picolinate on insulin controlled parameters in humans. *Int J Biosocial Med Research* 1989(a); **11**: 163–180.
24 Evans GW. The picolinates–How they help build muscle without steroids–and their other health benefits. In: Passwater RA, Mindell E (eds). *A good health guide*. Keats Publishing: New Canaan, 1989(b): pp 1–24.
25 Astrup A, Toubro S, Cannon S, Hei P, Breum L, Madson J. Caffeine: a double-blind, placebo-controlled study of its thermogenic, metabolic, and cardiovascular effects in healthy volunteers. *Am J Clin Nutr* 1990; **51**: 759–767.
26 Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem* 1972; **18**: 499–502.
27 Marken Lichtenbelt WDv, Westerterp KR, Wouters L, Luijendijk SCM. Validation of bioelectrical-impedance measurements as a method to estimate body-water compartments. *Am J Clin Nutr* 1994; **60**: 159–166.
28 Marken Lichtenbelt WDv, Snel YEM, Brummer R-JM, Koppeschaar HPF. Deuterium and bromide dilution, and bioimpedance spectrometry independently show that growth hormone-deficient adults have an enlarged extracellular water compartment related to intracellular water. *J Clin Endocrin Metab* 1997; **82**: 907–911.
29 Becel, Nederlandse Voedingsstoffenbestand (NEVO): Dutch nutrient database 1989/1990. Zeist, The Netherlands: Stichting NEVO, 1989 (in Dutch).
30 Pasman WJ, Westerterp-Plantenga MS, Muls E, Vansant G, van Ree J, Saris WHM. The effectiveness of long-term fibre supplementation on weight maintenance in weight-reduced women. *Int J Obes* 1997; **21**: 548–555.
31 Siggaard R, Raben A, Astrup A. Weight loss during 12 weeks' ad libitum carbohydrate-rich diet in overweight and normal-weight subjects at a Danish work site. *Obes Res* 1996; **4**: 347–356.
32 Shah M, McGovern P, French S, Baxter J. Comparison of a low-fat, ad libitum complex-carbohydrate diet with a low-energy diet in moderately obese women. *Am J Clin Nutr* 1994; **59**: 980–984.
33 Flatt JP. Dietary fat, carbohydrate balance, and weight maintenance. *Ann N Y Acad Sci* 1993; **683**: 122–140.
34 Prewitt TE, Schmeisser D, Bowen PE, Aye P, Dolecek TA, Langenberg P, Cole T, Brace, L. Changes in body weight, body composition, and energy intake in women fed high- and low-fat diets. *Am J Clin Nutr* 1991; **54**: 304–310.
35 Raben A, Astrup A. Manipulating carbohydrate content and sources in obesity prone subjects: effect on energy expenditure and macronutrient balance. *Int J Obes* 1996; **20**: S24–S30.
36 Gray DS, Bray GA, Bauer M, Kaplan K, Gemayel N, Wood R, Greenway F, Kirk S. Skinfold thickness measurements in obese subjects. *Am J Clin Nutr* 1990; **51**: 571–577.
37 Kooy Kvd, Leenen R, Deurenberg P, Seidell JC, Westerterp KR, Hautvast JGAJ. Changes in fat-free mass in obese subjects after weight loss: a comparison of body composition measures. *Int J Obes* 1992; **16**: 675–683.
38 Trent LK, Thieding-Cancel D. Effects of chromium picolinate on body composition. *J Sports Med Phys Fitness* 1995; **35**: 273–280.
39 Lukaski HC. Methods for the assessment of human body composition: traditional and new. *Am J Clin Nutr* 1987; **46**: 537–556.

40 Clancy SP, Clarckson PM, DeCheke ME, Nosaka K, Freedson PS, Cunningham JJ, Valentine B. Effects of chromium picolinate supplementation on body composition, strength, and urinary chromium loss in football players. *Int J Sport Nutr* 1994; **4**: 142–153.

41 Hallmark MA, Reynolds TH, DeSouza CA, Dotson CO, Anderson RA, Rogers MA. Effects of chromium and resistive training on muscle strength and body composition. *Med Sci Sports Exerc* 1996; **28**: 139–144.

42 Kaats GR, Blum K, Fisher JA, Adelman JA. Effects of chromium picolinate supplementation on body composition: a randomized, double-masked, placebo-controlled study. *Current Ther Res* 1996; **57**: 747–756.

43 Newman HAI, Leighton RF, Lanese RR, Freedland NA. Serum chromium and angiographically determined coronary artery disease. *Clin Chem* 1978; **24**: 541–544.

44 Anderson RA, Kozovsly AS. Chromium intake, adsorption and excretion of subjects consuming self-selected diets. *Am J Clin Nutr* 1985; **41**: 1177–1183.

45 Uusitupa MIJ, Mykkanen L, Siitonen O, Laakso M, Sarlund H, Kolehmainen P, Räsänen T, Kumpulainen J and Pyörälä: Chromium supplementation in impaired glucose tolerance of elderly: effects on blood glucose, plasma insulin, C-peptide and lipid levels. *Br J Nutr* 1992; **68**: 209–216.

46 Toubro S, Astrup A, Breum L, Qyaade F. The acute and chronic effects of ephedrine/caffeine mixtures on energy expenditure and glucose metabolism in humans. *Int J Obes* 1993; **17 (Suppl.3)**: S73–S77.

47 Pasman WJ, Wauters M, Westerterp-Plantenga MS, Saris WHM. Effect of one week of fibre supplementation on hunger and satiety or energy intake. *Appetite* 1997; **29**: 77–87.